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Infant feeding and adult glucose tolerance, lipid profile, blood pressure, and obesity

A C J Ravelli, J H P van der Meulen, C Osmond, D J P Barker, O P Bleker

Abstract

Background—It is generally accepted that breast feeding has a beneficial effect on the health of infants and young children. Recently, a few studies have shown that this method of infant feeding is also associated with cardiovascular disease and its risk factors in adult life.

Aims—To examine the association between the method of infant feeding in the first weeks after birth and glucose tolerance, plasma lipid profile, blood pressure, and body mass in adults aged 48–53 years.

Methods—Subjects born at term between 1 November 1943 and 28 February 1947 in the Wilhelmina Gasthuis in Amsterdam around the time of a severe period of famine (late November 1944 to early May 1945). For 625 subjects, information was available about infant feeding at the time of discharge from hospital (on average 10.4 days after birth), and at least one blood sample after an overnight fast.

Results—Subjects who were bottle fed had a higher mean 120 minute plasma glucose concentration after a standard oral glucose tolerance test than those who were exclusively breast fed. They also had a higher plasma low density lipoprotein (LDL) cholesterol concentration, a lower high density lipoprotein (HDL) cholesterol concentration, and a higher LDL/HDL ratio. Systolic blood pressure and body mass index were not affected by the method of infant feeding.

Conclusions—Exclusive breast feeding seems to have a protective effect against some risk factors for cardiovascular disease in later life.

(Arch Dis Child 2000;82:248–252)

Keywords: breast feeding; non-insulin dependent diabetes mellitus; cholesterol; blood pressure; obesity

It is generally accepted that breast feeding has a beneficial effect on the health of infants and young children. Its major advantages are that it protects against infections and allergic disorders and promotes neurodevelopment. Only a few studies have addressed its effects beyond the first year of life, whereas the cholesterol concentrations were unrelated to the method of infant feeding in women. Studies in children found the highest cholesterol concentrations in the group who had been breast fed for more than six months. Other studies showed associations between breast feeding and lower cholesterol concentrations, more clearly however in women than in men. Thirdly, blood pressure was shown to be significantly raised in children aged 6 to 10 if they were exclusively breast fed for more than 15 weeks. Another study indicated that blood pressure was higher in children and adolescents if they were breast fed for more than three months. Other studies however did not find associations between infant feeding and blood pressure. Lastly, it was also shown that a shorter duration of breast feeding was associated with obesity in children and adolescents and that the introduction of solids before 15 weeks was associated with heavier and fatter children in the age range 6–10 years.

Recently, we studied the relation between maternal nutrition during gestation and biological risk factors for cardiovascular disease in a cohort of subjects aged about 50 years, who were born between 1943 and 1947 in a university hospital in Amsterdam around the time of the Dutch famine, a period of severe malnutrition in the last five months of the second world war. We found that exposure to famine during late and mid gestation was linked to impaired glucose tolerance, and exposure in early gestation to a more atherogenic lipid profile and, in women, to an increased level of obesity. A link between prenatal exposure to famine and blood pressure could not be shown.

In the same cohort, we also studied the relation between the method of infant feeding during the stay in hospital, which lasted on average 10 days, and these risk factors for cardiovascular disease. We compared glucose tolerance, plasma lipid concentrations, blood pressure, and level of obesity in subjects who had been exclusively breast fed during the first 10 days of their life with those who were at least partly bottle fed.
Subjects and methods
The design and data collection procedure of the Dutch Famine Birth Cohort Study has been described in detail elsewhere. We retrieved the medical records of all 1380 singletons born alive after 37 weeks of gestation between 1 November 1944 and 28 February 1946 in the Wilhelmina Gasthuis in Amsterdam. We also retrieved the medical records of random samples of 650 of the 1305 babies born in the year before this period and of 650 of 2391 babies born in the following year. Of these babies, 27 (1.0%) were excluded because their medical record could not be found, and 239 (8.9%) were excluded because the gestational age at birth was below 259 days. Therefore, 2414 subjects were eligible to be included. We invited 912 subjects who still lived in or close to Amsterdam to visit the Academic Medical Centre after an overnight fast. Of these, 32 (3.5%) were excluded because they had been diagnosed with diabetes mellitus in the past. A total of 741 subjects attended the clinic between March 1995 and August 1996.

We took the method of infant feeding at the day of hospital discharge from the medical records, and classified it as exclusive breast feeding, partial bottle feeding, or exclusive bottle feeding. The method of infant feeding was missing in 67 subjects. We also considered the method of feeding to be missing if the hospital stay was less than seven days (10 subjects) or more than 31 days (16 subjects). Of the 648 participants with information about infant feeding, 625 had a fasting blood sample taken.

Birth weights among these 625 participants differed neither from the remainder of the 2414 subjects who were originally eligible, nor from the remainder of the 912 subjects who were invited to attend the clinic. Maternal characteristics and birth data were also abstracted from the medical records. Socioeconomic status at birth was determined from the occupation of the head of the family, which was dichotomised into manual and non-manual class. Current socioeconomic status was determined from the subject’s or their partner’s occupation, whichever was highest, according to a scale that represents the education needed for it and the income generated by it, ranging from 16 for the lowest to 87 for the highest status. We performed an oral glucose tolerance test, taking blood samples at 0, 30, and 120 minutes after a 75 g oral glucose load. The fasting insulin and 32–33 split proinsulin concentrations were considered as a measure of insulin resistance, because they reflect the degree of exposure of the pancreatic beta cell to glucose and so to increased demands for insulin. The 30 minute relative insulin increment log ((30 min insulin − fasting insulin)/30 min glucose) was calculated as a measure of insulin deficiency. We also took fasting blood samples to measure lipid and lipoprotein concentrations. Blood pressure was the average of four measurements in the non-dominant arm, taken twice before and twice after the other examinations with an automated auscultatory device (Profilomat), while the subjects were seated for at least five minutes. We measured waist circumference midway between the costal margin and iliac crest and hip circumference at the widest part of the hips, generally at the level of the greater trochanter. Body mass index was calculated as weight (kg) divided by the square of height (m^2).

Subjects were considered to be exposed to famine in utero if the official daily rations set weekly by the authorities were less than 1000 calories (0.00418 MJ) during any 13 week period of gestation. According to this definition, babies born between 7 January 1945 and 28 April 1945 were exposed in late gestation, babies born between 29 April 1945 and 18 August 1945 were exposed in mid gestation, and babies born between 19 August 1945 and 8 December 1945 were exposed in early gestation. The official rations for children younger than one year were always higher than 1000 calories, which indicates that they were relatively protected against undernutrition. Pregnant and lactating women received food supplements of about 4000 calories (0.01672 MJ) per week, but during the early months of 1945 these supplements were not always available.

We compared the differences between subjects who were exclusively breast fed and those who were at least partly bottle fed with multiple linear regression for continuously distributed variables and logistic regression for the dichotomous indicator of impaired glucose tolerance (120 minutes plasma glucose concentration ≥ 7.8 mmol/l). We log transformed some continuous variables before analysis because of their skewed distributions. We tabulated these variables as geometric means and standard deviations, and presented the relative differences between feeding methods. We always adjusted for sex, prenatal exposure to famine in late, mid, or early gestation, maternal age, and length of hospital stay when testing differences. In a second step, we also adjusted for other maternal characteristics, birth outcomes, and adult characteristics.

Results
Of the 625 subjects included in this study, 520 (83.2%) had been exclusively breast fed during their stay in hospital, 99 (15.8%) were partly bottle fed, and six (1.0%) were exclusively bottle fed. The proportion of subjects who had been exclusively breast fed varied slightly according to prenatal exposure to famine: 82 of 101 (81.2%) in those exposed to famine during late gestation; 80 of 91 (87.9%) in those exposed during mid gestation; and 54 of 63 (85.7%) in those exposed during early gestation (table 1). People who had been exclusively breast fed were more often men, had younger mothers who suffered less often from mastitis, and they were discharged from hospital about two days earlier. All other characteristics did not differ appreciably according to the method of feeding.

When adjusting for sex, prenatal exposure to famine, maternal age, and length of hospital stay, we found that subjects who were bottle fed
had higher 120 minute plasma glucose concentrations and a higher prevalence of impaired glucose tolerance than those who were exclusively breast fed (table 2). They also had higher fasting insulin and 32–33 split proinsulin concentrations, which suggests some degree of insulin resistance. The 30 minute relative insulin increment, a measure of insulin deficiency, did not differ according to the method of infant feeding. Fasting LDL cholesterol and apolipoprotein B concentrations were higher in those feeding. Fasting LDL cholesterol and apolipo-protein B concentrations were higher in those who were breast fed, as well as the LDL/HDL (high density lipoprotein) cholesterol ratios, which indicates a more atherogenic lipid profile. Systolic and diastolic blood pressures did not differ according to the method of infant feeding, neither did the level of obesity in terms of body mass index and waist circumference, and the body fat distribution in terms of waist to hip ratio.

None of these results changed appreciably when we adjusted additionally for other maternal characteristics (parity, level of education, socioeconomic status), birth characteristics (birth weight, stay in incubator), and adult characteristics (socioeconomic status, level of education). For example, after adjustment for all these variables, 120 minute glucose concentration was 10.1% (95% confidence interval 2.7 to 18.1) higher, fasting insulin concentration was 15.8% (3.3 to 30.0) higher, fasting 32–33 split proinsulin concentration was 27.6% (8.5 to 50.1) higher, LDL cholesterol concentration was 0.22 mmol/l (0.00 to 0.43) higher, HDL cholesterol concentration was 5.6% (0.3 to 10.7) lower, LDL/HDL ratio was 11.4% (2.2 to 21.5) higher, and triglyceride concentration was 8.3% (−3.6 to 21.8) higher among those bottle fed than among those exclusively breast fed.

The differences according to the method of infant feeding with respect to the insulin–glucose metabolism seemed to be similar in men and women. For example, the 120 minute glucose concentration was 8.6% (~2.1 to 20.3) higher in at least partly bottle fed men, and 12.3% (2.3 to 23.3) higher in at least partly bottle fed women, compared with those who were exclusively breast fed. The differences with respect to the lipid concentrations however seemed to be, albeit not significantly, larger among women than among men. We found among women that LDL cholesterol concentration was 0.30 mmol/l (0.00 to 0.60) higher, HDL

### Table 1 Characteristics at birth by infant feeding

<table>
<thead>
<tr>
<th></th>
<th>Exclusively breast fed</th>
<th>Bottle fed</th>
<th>Total (SD)</th>
<th>Missing observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of participants (n)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>520</td>
<td>105</td>
<td>625</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>48.8</td>
<td>45.7%</td>
<td>48.3%</td>
<td>0</td>
</tr>
<tr>
<td><strong>Exposure to famine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In late gestation (n)</td>
<td>82</td>
<td>19</td>
<td>101</td>
<td>0</td>
</tr>
<tr>
<td>In mid gestation (n)</td>
<td>80</td>
<td>11</td>
<td>91</td>
<td>0</td>
</tr>
<tr>
<td>In early gestation (n)</td>
<td>54</td>
<td>9</td>
<td>63</td>
<td>0</td>
</tr>
<tr>
<td>Not exposed during gestation</td>
<td>304</td>
<td>66</td>
<td>370</td>
<td>0</td>
</tr>
<tr>
<td><strong>Maternal characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>28.7</td>
<td>31.2</td>
<td>29.1 (6.5)</td>
<td>0</td>
</tr>
<tr>
<td>Primaiparous</td>
<td>32.9%</td>
<td>35.2%</td>
<td>33.3%</td>
<td>0</td>
</tr>
<tr>
<td>Low level of education†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low level of education*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual class</td>
<td>63.5%</td>
<td>62.8%</td>
<td>63.4%</td>
<td>103</td>
</tr>
<tr>
<td>Weight gain 3rd trimester (kg)</td>
<td>3.5</td>
<td>3.6</td>
<td>3.5 (3.2)</td>
<td>176</td>
</tr>
<tr>
<td>Weight last prenatal visit (kg)</td>
<td>66.2</td>
<td>65.3</td>
<td>66.1 (8.5)</td>
<td>71</td>
</tr>
<tr>
<td>Mxatitis</td>
<td>2.7%</td>
<td>5.7%</td>
<td>3.2%</td>
<td>0</td>
</tr>
<tr>
<td><strong>Birth characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age (days)</td>
<td>285</td>
<td>285</td>
<td>285 (12)</td>
<td>81</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>3366</td>
<td>3326</td>
<td>3359 (460)</td>
<td>0</td>
</tr>
<tr>
<td>Length of hospital stay after birth (days)</td>
<td>10.2</td>
<td>11.8</td>
<td>10.4 (3.4)</td>
<td>0</td>
</tr>
<tr>
<td>Stay in incubator</td>
<td>1.9%</td>
<td>4.8%</td>
<td>2.4%</td>
<td>0</td>
</tr>
<tr>
<td><strong>Adult characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>47.5</td>
<td>48.2</td>
<td>47.6 (13.6)</td>
<td>0</td>
</tr>
<tr>
<td>Low level of education†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Primary school completed or lower.
†Lower general secondary education completed or lower.

### Table 2 Geometric means (SD) of adult outcomes by infant feeding

<table>
<thead>
<tr>
<th></th>
<th>Exclusively breast fed (n = 520)</th>
<th>Bottle fed (n = 105)</th>
<th>Total (SD) (n = 625)</th>
<th>p Value*</th>
<th>Missing observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oral glucose tolerance test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fasting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose (mmol/l)†</td>
<td>5.69</td>
<td>5.87</td>
<td>5.72 (1.2)</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>Insulin (pmol/l)†</td>
<td>46.4</td>
<td>52.7</td>
<td>47.4 (1.7)</td>
<td>0.01</td>
<td>8</td>
</tr>
<tr>
<td>Fasting 32–33 split proinsulin (pmol/l)†</td>
<td>5.84</td>
<td>6.67</td>
<td>5.97 (1.9)</td>
<td>0.01</td>
<td>9</td>
</tr>
<tr>
<td>30 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose (mmol/l)†</td>
<td>8.80</td>
<td>9.10</td>
<td>8.85 (1.3)</td>
<td>0.07</td>
<td>17</td>
</tr>
<tr>
<td>Insulin (pmol/l)†</td>
<td>307.4</td>
<td>312.2</td>
<td>308.2 (1.6)</td>
<td>0.6</td>
<td>25</td>
</tr>
<tr>
<td>Insulin increment</td>
<td>3.36</td>
<td>3.35</td>
<td>3.36 (0.7)</td>
<td>0.9</td>
<td>32</td>
</tr>
<tr>
<td>120 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose (mmol/l)†</td>
<td>5.87</td>
<td>6.47</td>
<td>5.97 (1.4)</td>
<td>0.005</td>
<td>9</td>
</tr>
<tr>
<td>Glucose ≥ 7.8 mmol/l</td>
<td>13.8%</td>
<td>24.3%</td>
<td>15.6%</td>
<td>0.006</td>
<td>9</td>
</tr>
<tr>
<td>Insulin (pmol/l)†</td>
<td>5.18</td>
<td>5.30</td>
<td>5.20 (0.9)</td>
<td>0.3</td>
<td>17</td>
</tr>
<tr>
<td><strong>Lipids</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cholesterol (mmol/l)</td>
<td>5.95</td>
<td>6.11</td>
<td>5.97 (1.0)</td>
<td>0.1</td>
<td>3</td>
</tr>
<tr>
<td>LDL cholesterol (mmol/l)</td>
<td>3.96</td>
<td>4.15</td>
<td>3.99 (1.0)</td>
<td>0.06</td>
<td>3</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/l)†</td>
<td>1.34</td>
<td>1.27</td>
<td>1.33 (1.3)</td>
<td>0.03</td>
<td>3</td>
</tr>
<tr>
<td>LDL/HDL ratio</td>
<td>2.86</td>
<td>3.14</td>
<td>2.90 (1.5)</td>
<td>0.01</td>
<td>3</td>
</tr>
<tr>
<td>Triglyceride (g/l)</td>
<td>1.13</td>
<td>1.19</td>
<td>1.14 (1.7)</td>
<td>0.1</td>
<td>3</td>
</tr>
<tr>
<td>Apolipoprotein A1 (g/l)</td>
<td>1.54</td>
<td>1.52</td>
<td>1.54 (0.3)</td>
<td>0.4</td>
<td>6</td>
</tr>
<tr>
<td>Apolipoprotein B (g/l)</td>
<td>1.21</td>
<td>1.27</td>
<td>1.22 (0.3)</td>
<td>0.07</td>
<td>6</td>
</tr>
<tr>
<td><strong>Blood pressure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diastolic (mm Hg)</td>
<td>85.7</td>
<td>84.8</td>
<td>85.6 (10.1)</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Systolic (mm Hg)</td>
<td>125.1</td>
<td>124.9</td>
<td>125.1 (15.4)</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td><strong>Anthropometry</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.8</td>
<td>27.2</td>
<td>26.9 (1.2)</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>91.9</td>
<td>93.2</td>
<td>92.1 (12.8)</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Waist to hip ratio (x 100)</td>
<td>87.3</td>
<td>87.7</td>
<td>87.4 (8.8)</td>
<td>0.1</td>
<td>2</td>
</tr>
</tbody>
</table>

*p Value adjusted for prenatal exposure to famine, maternal age, sex, and hospital duration.
†Geometric mean.
Relation between infant feeding and cardiovascular disease

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must be protected and the o

under 3 years were regarded as a group that

pressure or body mass, neither of which were

associations between infant feeding and blood

education, one would have expected to find

confounded by, for example, socioeconomic

respect, that if the associations between infant

feeding. It is also important to note in this

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feeding and glucose tolerance or lipid profile. It

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bottle feeding was very rare. The characteris-

breast fed and the remainder, because exclusive

tinguished between those who were exclusively

method infant of feeding as it was noted in the

baboons had a more atherogenic profile, espe-

findings, these studies showed that breast fed

women were entitled to additional weekly

McGill

Secondly, lactating

baby immediately be-

and after breast feeding indicated an

that this exposure to undernutrition of the

number of arguments indicate that it is unlikely

this study were exposed to famine in utero. A

women were entitled to additional weekly

milk with adequate content of protein, fat, car-

have shown that women are able to produce

primary gland and absorbed by the child, thereby

recently that leptin is produced in the mam-

tasis induced by the observed higher circulat-

nently a

Whatever the underlying factors may be, our

findings correspond largely with those of previ-

ous studies on associations of infant feeding for

discussion

We found that 50 year old subjects who had

been at least partly bottle fed during the first

weeks of life had a lower glucose tolerance,

possibly owing to some degree of insulin resist-

ance, and a more atherogenic lipid profile than

those who had been exclusively breast fed. The
deleterious effects of bottle feeding on the lipid

profile seemed to be slightly stronger in women

than in men. The method of infant feeding did

not affect adult blood pressure or body mass.

This study is based on information about the

method infant of feeding as it was noted in the

medical records at discharge. We only dis-

tinguished between those who were exclusively

breast fed and the remainder, because exclusive

bottle feeding was very rare. The characteris-

tics of these two groups were remarkably simi-

lar. Adjusting for these characteristics did not

affect the associations between method of

feeding and glucose tolerance or lipid profile.

It is therefore unlikely that our findings can be

merely attributed to differences in biological or

behavioural determinants of the method of

feeding. It is also important to note in this

respect, that if the associations between infant

feeding and adult health outcomes were

confounded by, for example, socioeconomic

status at birth or at adult age, or the level of

education, one would have expected to find

associations between infant feeding and blood

pressure or body mass, neither of which were

found.28

About 40% of the subjects included in this

study were exposed to famine in utero. A

number of arguments indicate that it is unlikely

that this exposure to undernutrition of the

women and their babies has affected the

associations found between bottle feeding and

the reduced glucose tolerance and atherogenic

lipid profile at adult age. Firstly, our figures

indicate that 81.2% of the mothers who were

undernourished during pregnancy (those who

gave birth during the famine period) were

able to exclusively breast feed their babies

compared to 83.6% of the others. In those

days, additional bottle feeding was given, if

weighing the newborn baby immediately be-

fore and after breast feeding indicated an

insufficient milk supply.29 Secondly, lactating

women were entitled to additional weekly

supplies.27 Moreover, a large number of studies

have shown that women are able to produce

milk with adequate content of protein, fat, car-

bohydrate, and most minerals even when their

own nutrition is limited.27 Thirdly, children

under 3 years were regarded as a group that

must be protected and the official rations for

this group never fell below 1000 calories, which

was adequate according to the then prevailing

standards.28

We do not have information about the

method of infant feeding after discharge from

hospital, which took place on average 10 days

after birth, but we still found relatively large
deleterious effects on glucose tolerance and

cholesterol concentrations in adult life. In

those days, women were advised to breast feed

their babies exclusively for seven to nine

months.28 It is therefore likely that those who

were exclusively breast feeding their babies at

discharge tried to maintain breast feeding for at

least several months. This view is corroborated

by figures kept by the Municipal Health

Authority of Amsterdam in the years immedi-

ately before the second world war which show

that about 55% of the babies were still

exclusively breast fed at the age of 3 months.31

Moreover, Dutch paediatricians had the im-

pression that the duration of breast feeding was

not greatly affected during the famine.32 Bottle

feeds most commonly consisted of diluted
cows’ milk (milk and water in the proportion of

1:1 or 2:1) with some added sugar, or

buttermilk with rice flour and sugar, which

gave it a similar energy content, but a higher

protein and lower fat content than human

milk.32

Which factors could explain the effects of

breast feeding on insulin–glucose and lipid

metabolism? One explanation is that the

considerable increases in fat content which are

present during breast feeding but not during

bottle feeding might provide a satiety signal,

which protects against overfeeding.35 36 Fur-

thermore, it has been shown that bottle fed

babies have a different hormonal response of

which the higher insulin response is of particu-

lar interest.35 Since the early 1970s, a large

number of experiments with the baboon as an

animal model were performed to investigate

through which mechanism lipid metabolism is

affected by breast feeding or infant feeding (see

McGill et al36 for review). In contrast to our

findings, these studies showed that breast fed

baboons had a more atherogenic profile, espe-

cially lower HDL cholesterol concentrations,

throughout their life than bottle fed ones. More

detailed studies eliminated nutritional factors

such as cholesterol content, type of fat, or

under- or overfeeding as mechanisms by which

infant nutrition affects lipid metabolism in

adult life. This suggests that biologically active

substances like growth factors or hormones

that are contained in breast milk are respon-

sible for the effect on lipid metabolism.37 For

instance, lipid metabolism might be perma-

nently affected by changes in thyroid homeos-

tasis induced by the observed higher circulat-

ing triiodothyronine concentrations in the

bottle fed animals. It has also been shown

recently that leptin is produced in the mam-

mary gland and absorbed by the child, thereby

potentially influencing growth and

development.38 39

Whatever the underlying factors may be, our

findings correspond largely with those of previ-

ous studies on associations of infant feeding.
with specific risk factors for cardiovascular disease. The associations of bottle feeding with insulin resistance and an atherogenic lipid profile, but not with hyperinsulinemia or obesity suggest that nutrition during early life is not the “common soil” that contributes to the “insulin resistance syndrome”, the occurrence of these risk factors for cardiovascular disease in the same person, which is in agreement with our observations in the same group of subjects with respect to different effects of prenatal exposure to famine on glucose tolerance, lipid profile, obesity, and blood pressure.22–23

Our results support the hypothesis that the method of infant feeding is an important determinant of health in adult life. Babies who were exclusively breast fed during the first days of their life had favourable outcomes with respect to glucose and lipid metabolism, which relates to a lower risk of cardiovascular disease. However, our understanding of the mechanisms linking infant nutrition and cardiovascular disease is poor.24 Because of the potential importance for the prevention of cardiovascular disease, it is important that the research in the area of infant nutrition should also focus on biological effects in later life.18

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